NOTES ON THE RECENT ERUPTIONS IN THE TAUPO ZONE, NEW ZEALAND.

By Professor Stephens, M.A., F.G.S., &c.

In throwing together a few notes upon the recent eruptions in the Taupo Zone of New Zealand, I have been actuated solely by a desire that the groundwork of the extraordinary phenomena which have attracted our attention to that district during the last month might be more clearly presented to our minds than it is at present, and that in this way the exact and detailed accounts of those disasters which we shall by and by receive may be the more readily appreciated and interpreted. It is hardly necessary to premise that there is little, if any, original work in this paper, the object of which is only to diffuse more generally the information which is already sufficiently ascertained. It is likewise unnecessary to remark that the reports which have as yet appeared in our newspapers are imperfect and contradictory, and must therefore be to a greater or less extent erroneous and misleading. I had hoped to have a more consistent history of these events before me at the time when I am now writing (June 28). But it is probable that we may have to wait for some considerable time longer before a full examination of the records of the eruptions as derived from eye-witnesses, and of the more important evidence obtained from subsequent exploration of the new ground, and from the investigation of its transformations by the violent operations to which it has been subjected, can be so far completed as to give the world a full history of these phenomena and a satisfactory explanation of their causes.

In the meantime, therefore, a brief sketch of the Geographical and Geological characters of the disturbed district may be of some little service to those who desire to obtain a rational and

coherent idea of the extraordinary phenomena of which, as I have said, we have as yet but confused and broken accounts. The more so, because the chief sources of our information, in the extremely valuable descriptions and maps of the late distinguished Geologist, Ferdinand von Hochstetter, are by no means readily or generally available in Sydney.

It was in the year 1859 that this explorer started from Auckland in March to investigate the country previously though hastily examined by Dieffenbach in 1840. He reached Lake Taupo in April, after a rather discursive journey made partly in Maori canoes and partly on foot, and at once devoted himself to the survey and geological examination of the district. Thence he proceeded to trace the manifold series of hot springs and allied phenomena which crowd the banks of the Waikato and its tributaries, to the point where it strikes away, from the still more energetically volcanic area of Rotomahana, Rotorua and Tarawera into the gorge which conducts its waters to the Middle Waikato district.

From this point he diverged into the famous Lake Region, where he remained until May. In this flying survey he succeeded in laying down a clear and trustworthy draft of the most remarkable points in a very remarkable region, second in interest to none, in his opinion, except the somewhat similar Geyser District of Iceland. The third great collection of allied phenomena, and in many respects the most noteworthy of all, the Yellowstone River Geysers, in the Upper Missouri basin, was at the time comparatively unknown. At any rate he does not, so far as I recollect, even allude to it. I do not doubt that much has been added, by way of filling in, to Hochstetter's sketch, but I have not myself met with any descriptions which have a higher aim than the production of picturesque images for the lovers of the extraordinary, whether in the natural features of the landscape, or in the mode of life of the people who dwell among them; and certainly none which can be considered to supersede his account from a scientific point of view.

The Northern Island of New Zealand, inhabited by a race of Maoris far more hot-blooded and volcanic in temperament than their congeners in the Middle portion of this half-insular half-continental region, is in itself likewise distinguished by the fiery and stormy conditions of its subterranean energies from its more mature and tranquil neighbour. The forces which have been at work in the Middle Island have long been reduced to the condition of strains and tensions, which as they gradually overpower the resistance which deeply folded masses of rock oppose to their energy, may perhaps result in earthquakes, but no longer cause, and probably never again will cause, true volcanic action.

But in the Northern Island, however ancient the origin or first outbreak of these eruptive forces may be, they have continued to the present day, enfeebled indeed like all other forces by expenditure of energy and lapse of time, but still furnishing us with a sort of museum of specimens for all kinds of volcanic actions and products, which has not as yet been quite sufficiently arranged, or even catalogued for scientific purposes.

The turbulent and dangerous fanaticism of certain tribes of Maoris has been, I presume, the main cause of the still existing obscurity and uncertainty upon these heads. This, however, no longer remaining as an obstacle, and a staff of most competent observers being naturally summoned to the scene by the thunders of Tarawera, we may confidently look forward to a not distant period when this district shall be as thoroughly studied and familiar to the geologist as that of Vesuvius.

The cordillera or backbone of the mountain system of New Zealand runs in a general direction from N.E. to S.W. This structure is clearly shown by the sea-contour of the Middle and South Islands, but is masked in the North Island by a broad spur or N.W. upheaval which brings the northern line of emergence into a position almost at right angles to the main strike of the rocks which form the southern mass. N.E. of Cook's Straits, however, these older formations retain their leading bias of fold and something of their altitude. They form the south-west coast which stretches from Wellington to East

Cape, extending inwards to a rather uniform distance of about 50 miles, and are flanked on both sides by volcanic tertiaries. The formation, however, of the central portion which belongs to the Maitai series of Dr. Hector, is, according to his determination, of Lower Carboniferous character. They correspond consequently to the rocks of the same or approximate period with which we are familiar on the northern and southern flanks of our Upper Carboniferous area, and though much more remains to be worked out in both countries, the general conclusions at which Dr. Hector has arrived are not likely to be much modified. (1)

Now this S.E. coast range (known as the Rimutaka, Tararua, Ruahine and Kaimanawa ranges) in its run of over 300 miles from Cook's Straits to East Cape, is flanked on its N.W. side by a broad tract of country the original formation of which has been completely broken up and obliterated by volcanic action, and whose N.W. slope has been fractured, dislocated and overwhelmed on a gigantic scale. For the characteristic Maitai rocks do not reappear except in small isolated scraps until they emerge as ranges or parallel folds with a N.N.W. trend, starting from a line running N.E. from Aotea. The bearing of these ridges, which flank the Middle Waikato and the Thames, is therefore inclined at an obtuse angle to the original strike of the S.E. range.

All the intervening ground is covered with the results of volcanic action. In the first place, from the Bay of Plenty to the Bay of Wanganui there stretches N.W. of the Ruahine Ranges a long and comparatively narrow valley, the general floor of which is formed of volcanic ejecta, mainly pumice, arranged in gradually sloping plains or successive terraces. The highest point or transverse watershed of this valley is marked by the twin giants Ruapehu, an extinct volcano over 10,000 feet in height, and covered with perpetual snow and glaciers, and Tongariro, which

(1) The chief and most characteristic fossils of the Maitai series are *Spirifera bisulcata*, *Productus brachytherus*, *Cyathophyllum*, and *Cyathocrinus*. (Hector, Handbook, N. Z., 1879, p. 26), and these are also enumerated among the Lower Carboniferous fossils of N. S. W. (Wilkinson's Report, &c., 1882.)

has maintained a certain amount of activity up to the present time. From this centre the Waikato, the Wanganui, and the Wangahu rivers take their respective courses. The north-western sides of this valley are formed by the edge of a vast plateau of trachytic lava, emitted probably from fissures in the first instance, though subsequently penetrated by a few cones of eruption. These appear to be more frequent in the less elevated portions of the plateau, and on the isolated patches which rise near its margin, a fact which may indicate a very great thickness in the central portion of this trachytic area. The whole plateau is densely wooded, and intersected with deep valleys, along two of which the Waikato and Wanganui make their way in divergent directions. To the N.W., but quite separated from these trachytes is the Pliocene basaltic plateau of the Lower Waikato. The former region therefore appears to be occupied by the oldest volcanic rocks which are to be found in the wide space between the Maitai rocks to the S.E., and their re-appearance on the Thames. And it would seem that these trachytes underlie the pumice beds of the Taupo Zone throughout, and that these latter just conceal the line of contact of the former with the aforesaid Maitai carboniferous rocks. For at both ends of the Taupo Lake, and in like manner to the N.E. of Tarawera, this trachytic formation emerges in insular patches from the pumice, supporting in each case true cones of eruption which have been subsequently thrown up through it. These are all represented by Hochstetter as having completed their periods of activity by forming a central cone or plug of a more silicious lava, rhyolite, within the crater of each. The same rock forms a margin to Lake Taupo, and further occupies the whole area of the Lake district.

Now this rock is of the same materials as Obsidian, which is its glassy condition, cooled rapidly, so as to prevent the separation of the constituent minerals, and under pressure, so as to compress whatever gaseous matters it might contain from normal expansion. Pumice on the other hand is the same material charged, in its original mass, with an enormous proportion of compressed gas (steam) which expanding as the lumps of liquid

rhyolite are hurled high into the air and relieved from even ordinary atmospheric pressure, forms a froth which is so immediately cooled and solidified as to retain its spongy character for ever. Of these materials the whole surface of the Taupo Zone is composed. No wonder then if heated alkaline waters percolating through very hot and soluble rocks of this kind in the Rotomahana country should become heavily impregnated with silica, to be deposited as their temperature falls, and upon exposure to the air, in those beautiful Sinter Terraces which have made the name of an otherwise insignificant little lake famous throughout the world. (1)

If we follow the Waikato from its sources on the N.E. flanks of Ruapehu and Tongariro, we shall see that it leaves upon the left the dormant volcanoes of the Kuharua District, rising from their more ancient base of trachytic lava, and still maintaining in their innumerable hot springs very sufficient evidence that their energies are not even now quite worn out. Thence it flows into the now tranquil basin of Lake Taupo, sunk as it were into the tertiary pumice beds, but revealing in its shores the almost unbroken rim of rhyolitic lava which underlies them.

From this lake the river itself and its tributaries, beset with boiling springs and geysers, leaves the Lake District on the right, and turning sharply to the north-west, cuts its way through the plateau to the broad expanse of the Middle Waikato.

It is remarkable that the very margins of the Lake District drain outwards to the Waikato, and not inwards to the lakes, though these lie at a lower level. And this seems to indicate that the water supplies for the hot springs of Rotomahana and its neighbourhood must travel by subterranean channels, and in an opposite direction to the surface drainage, in their course to ultimate emergence.

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(1) Dr. Hector has observed that the Sinter of the Lake District, deposited by heated landwaters, is represented in White Island, where sea-water alone has been concerned in the decomposition of the mother rock, by Sulphate of Lime.

Some of the subterranean streams which thus rise to the surface under considerable hydrostatic pressure may originate in the mountainous region to the S.E., and some portion may also probably be derived from Lake Taupo and the Waikato drainage. It is obvious that the springs must have their origin in the rainfall of some district of larger area than that limited basin from which the Kaituna and Tarawera flow. This is further divided into two minor basins, Rotorua to the East, which is only a few miles in diameter, and Tarawera, which is four times as wide, and it is encircled by a lofty barrier of rhyolitic lavas broken only to the N.E. for the outlet of the river Tarawera, and presenting the appearance of a vast general crater rim enclosing the separate crater lakes of Rotokakahi, Rotomahana and Tarawera.

It is worth notice that the water level of the first stands three hundred feet higher than that of the others, indicating an independent and probably later origin for this crater.

We are then in possession of these facts or reasonable inferences, —First, the area of the Lake district is as a whole about equal to that of Lake Taupo ; secondly, both tracts are surrounded with a rim of rhyolitic lava, the most recent of the local volcanic products, forming in the one case an elevated barrier or mountain ridge enclosing several lakes and mountains of volcanic origin, in the other a sunken wall capped by pumice deposits. Now Lake Taupo itself appears to have been formed by a long series of explosions from more than one volcanic vent within its circumference, rending away and dispersing their materials, and forming or at least assisting to form the great pumice deposits of the whole region to N.E. and S.W.

And it is impossible to avoid the conjecture that all this region, the Lake District, is undergoing a similar series of processes to that which has resulted in the formation of the older and single lake. By degrees, one would suppose, the greater portion of the solid elevations over this area may be blown away or sink into the cavities formed by successive explosions, until at last when the violence of the subterranean heat has been exhausted, a tranquil lake, like that of Taupo, may occupy the scene of the late and present turmoil.

It is noteworthy that the explosive centres are travelling to the N.E. : Ruapehu and others formerly active, but now extinct, and Tongariro at present still slightly active lie to the S.W. Then the hot springs of the Kuharua country, the geysers and hot springs of the Waikato, and, with still increasing activity, the Rotomahana marvels continue the chain to its N.E. culmination in the ever active insular volcano of White Island.

This gradual decrease in activity as we move to the S.W. along the line of disturbance seems to be in harmony with the view that the present condition of Taupo is only a more advanced stage of the same series of which we see some of the preceding steps in the late explosion, and that in the course of ages Tarawera and Rotorua will come to reproduce a basin of equal tranquillity for themselves.

If there has been in the case of Tarawera no actual eruption of lava from crater or fissure, there seems to have been at least an enormously increased energy of thermal action, involving the actual incandescence of steam and other gases, and of the materials which their discharge shot up in the clouds. And it does not seem probable that so great and so sudden a paroxysm could have been produced by any cause short of a real rise of the fluid rhyolitic lava, either up unseen funnels left by former explosive action, or up new rents, whose rupture might have caused the shocks of earthquake which appear to have been so frequent and so violent.

To what extent this lava may have been itself charged with steam under intense compression may be a question difficult of determination. But seeing how the whole country teems with springs, there is no difficulty in supposing that such a column of white-hot lava moving upwards would meet with abundance of percolating waters which it could almost instantaneously change into explosives of prodigious power.

The cessation of upward movement in the lava column, which must be consequent on so vast a loss of heat as is involved in the expenditure of so much steam power, will naturally give some intervals of comparative repose to the surface. But after a time

the subterranean pressures—whatever their origin may be—are likely to repeat their previous action, the fiery liquid will again rise through the water-bearing strata, and the same series of explosions recommence. While lava is free from water, either involved in its mass or in contact with it, its flow will be regular and its cooling gradual ; it will produce streams or hills or cones of lava, and will therefore tend to accumulate to some extent about its vent. When, however, the reverse is the case—and steam is generated at a white heat and under enormous pressure, the resulting explosions, as at Krakatoa, scatter into space not only the aforesaid accumulation, but also the new and active lava itself. (I leave out of consideration the ordinary process of cone formation with tuff, fragmentary lavas and pumice, as beside the present question, since neither Tarawera nor any of the other volcanic eminences about these lakes seem to have been so constructed). Such a rise in the temperature of the lower portions of the siphons of these springs as would be produced by a movement of molten rock towards the surface would certainly stimulate their action in the highest degree, while the more intense heat in the rocks in immediate contact with the lava would, as certainly, result in the rapid formation of intensely expansive steam under intense pressure, which, even if we put out of the question the steam which is originally or at least actually engaged in the lava itself, is sufficient to account for the tuff and pumice (if not lava) eruptions at Tarawera. Nor can one readily imagine any other cause which would readily bring about so sudden an access of violence in the ordinary action of hot springs, together with simultaneous volcanic discharges of very considerable intensity.

Geysers are but little dependent upon waters derived from a distance. They are not phenomena of the same kind as continuously flowing hot springs or artesian wells A very small quantity of water is sufficient to keep a large geyser in work, the outflow in many instances being inconsiderable. A heated stratum of rock, at no very considerable depth from the surface, perforated by a funnel or vertical pipe with orifice above, open to

the hot rock below, and receiving a small influx of percolating waters, is the only apparatus required. It is, however, curious to observe that geysers are at present confined to the three regions mentioned above—Iceland, the Yellowstone and the Taupo Zone ; and that the characteristic rock in each is rhyolitic lava of the same character. (1)

It will be very interesting to watch for further symptoms either of subsidence and quiescence of the subterranean forces, or of another outbreak which seems to me the more probable, and is indeed involved in my hypothesis of an upward movement of lava in the throat of Tarawera. If such actions should recommence we should be justified in feeling some apprehension of a renewal of true volcanic action, long, but how long no one can tell, dormant in this region.

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(1) At the last February meeting of the Geological Society, Professor Judd, F.R.S., &c.. exhibited photographs of the geysers and terraces of New Zealand, taken by J. Martin, Esq., F.G.S. In the instantaneous photographs of the geysers, the explosive action of the steam which is still engaged in the water after its rise into the air which might have been conjectured, but had never been observed before, is distinctly shown. 'The body of heated water, after its rise from the geyser-tube is seen to be violently dispersed, probably by a liberation of high pressure steam.'